23 (2025) 26–31

Contents lists available at ScienceDirect

Perspectives in Ecology and Conservation

journal homepage: www.perspectecolconserv.com

Essays and Perspectives

From silos to solutions: Navigating transdisciplinary conservation research for early career researchers

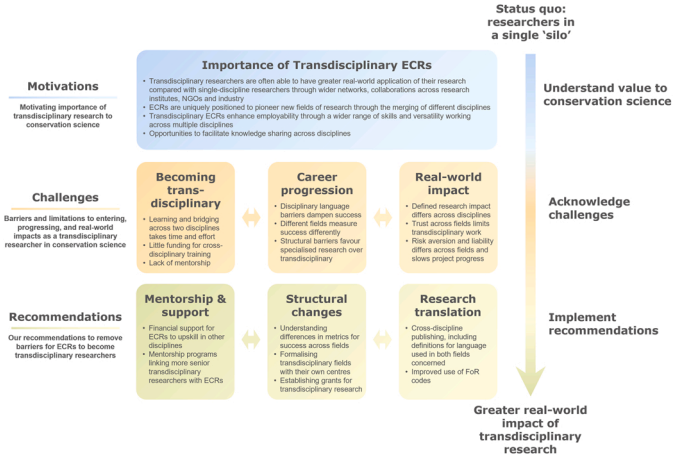
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HIGHLIGHTS

- Global conservation problems often require holistic, transdisciplinary solutions.
- Transdisciplinary ECRs face major challenges in collaboration and career growth.
- Current metrics fail to capture the real-world impact of transdisciplinary research.
- Transforming metrics and recognising transdisciplinary scientists is key.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Transdisciplinary
Early career researchers
Conservation science
Research impact

ABSTRACT

Conservation challenges are often intertwined with complex geopolitical challenges such as climate change and economic development, that cannot be solved through traditional single-discipline approaches. Whilst the benefits of transdisciplinary approaches are widely acknowledged, the integration of such approaches in conservation research and practice remains limited, underscoring a significant gap in current efforts to address global biodiversity and sustainability challenges. Early career researchers (ECRs) are ideally positioned to embrace and advance such approaches; however, the transition to transdisciplinary research results in many challenges for ECRs, from navigating the complexities of interdisciplinary collaborations to establishing a transdisciplinary research career. Drawing on the insights from our own journeys as transdisciplinary researchers, we outline key obstacles we have encountered and propose a set of actionable recommendations. These guidelines aim to support ECRs in overcoming the barriers to transdisciplinary work, facilitating the

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https://doi.org/10.1016/j.pecon.2024.12.002
Received 2 September 2024; Accepted 14 December 2024
Available online 21 February 2025
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broader application of these approaches in environmental conservation and beyond, and fostering a more integrated and effective response to global conservation challenges.

Introduction

Many of the environmental conservation challenges faced globally today are the result of complex interactions between human and natural systems (Game et al., 2014; Guerrero et al., 2018; Montti et al., 2024). Effective conservation solutions therefore require an understanding of the social, economic, and ecological systems in which conservation problems occur (Guerrero et al., 2018). Since environmental conservation issues are interrelated with other challenges such as climate change, economic development, and geopolitical security (Game et al., 2014), single-approach solutions are often inefficient and/or ineffective. For example, effective evaluation of the benefits of reforestation requires consideration of its carbon sequestration (Cook-Patton et al., 2020) and health benefits (Jones and Goodkind, 2019), drawing on insights from both climate science, economics and health disciplines, illustrating the necessity of combing knowledge from distinct fields and reconciling differences in values (Ludwig and El-Hani, 2020; Ludwig and Boogaard, 2021). Moreover, the complex nature of conservation problems means that the resources, funds, manpower, and political will allocated for a solution are frequently mismatched with the scale of the problem (Dallimer and Strange, 2015; Hertel et al., 2023). Transdisciplinary research goes beyond the fusion of two distinct fields (as seen in interdisciplinary research) by also integrating diverse perspectives, including those of academics and non-academics, including government officials, policymakers, and practitioners (Bammer et al., 2020; Ludwig and Boogaard, 2021). Transdisciplinary approaches can provide a way of bridging gaps between researchers in disparate fields, as well as between research and practitioners, to facilitate the development and application of robust and comprehensive solutions (Game et al., 2014; Bammer et al., 2020). Thus, transdisciplinary approaches are essential in addressing environmental conservation challenges, as they provide a structured pathway for uniting fragmented knowledge and aligning efforts across sectors to achieve sustainable solutions.

While calls for integrated transdisciplinary conservation approaches are not new (Balmford and Cowling, 2006; Reyers et al., 2010; Dick et al., 2016), broadening research scopes by including transdisciplinary approaches remains underutilised, despite their critical importance in addressing global biodiversity and sustainability challenges (Margules et al., 2020; Lawrence et al., 2022). ECRs are uniquely positioned to advance transdisciplinary solutions, because they are still developing their expertise and have not yet specialised in a single field, offering them flexibility in pursuing inter-, multi- and transdisciplinary research (Armitage et al., 2019). Due to the solution-focused nature of transdisciplinary approaches, early career researchers (ECRs) are increasingly adopting and applying transdisciplinary perspectives and approaches to address the world's most pressing sustainability challenges. However, ECRs face many challenges when navigating transdisciplinary research pathways and establishing a strong foundation for their research careers.

Here we draw on the perspectives of several transdisciplinary researchers working across different fields, presenting individual case studies and drawing out common themes from their experiences. We briefly describe the key challenges experienced and observed by the group of researchers and then provide a set of recommendations to overcome these challenges. These recommendations could offer valuable support and guidance for ECRs in navigating a transdisciplinary career, fostering the development and application of transdisciplinary approaches, and ultimately encouraging their broader adoption (Box 1).

Challenges to transdisciplinary research for ECRs

Challenges in becoming a transdisciplinary researcher include the daunting task of learning new fields without adequate incentives for career advancement and research impact, creating barriers to entry and progression within the transdisciplinary landscape. Here, we briefly outline some key challenges we have faced and can see within the academic system (Table 1).

Recommendations to overcome challenges of transdisciplinary research for ECRs

Given the identified challenges to ECRs undertaking transdisciplinary research, we suggest several recommendations for the field of conservation science to enhance career prospects and the real-world impact of transdisciplinary ECRs (Fig. 1).

Recommendation 1: Time and support to learn a new discipline

Breaking the cycle of limited time and financial support for ECRs to upskill in diverse research disciplines is crucial for fostering innovation and adaptability in academia. One solution involves providing scholarships and grants for PhD candidates to pursue formal training in new fields, allocating dedicated time during their candidature for this purpose. Embracing a model akin to industry accreditation programs that mandate continual professional development hours could be implemented for ECRs. This might entail including time in their contracts for skill development or providing a leave allowance for professional development. Additionally, time allowances could be made for ECRs to sit in on lectures held at their hosting institute to upskill in different fields. Many research institutions offer discipline specific courses such as field-specific statistics, hypothesis testing, grant writing, or programming, but here we are suggesting that courses be made available to ECRs in disciplines outside of their core area of expertise. The evolving landscape of academia, marked by the rise of double degrees, industry partnerships, placements, academic consultancy, and non-academic research institutes is reshaping how transdisciplinary research is perceived and supported.

Recommendation 2: Increase and broaden mentorship

ECRs can benefit greatly from mentorship, especially when coming from under-represented or marginalised groups (Gardiner et al., 2007; Ransdell et al., 2021). Given that transdisciplinary research has not been as prominent in traditional academia, and therefore senior

Box 1
Key Terms and Definitions.

Challenges	Barriers to career progression
Early career researchers (ECR)	Researchers within five years post-PhD
Higher degree by research (HDR) students	Postgraduate students including Masters and PhDs
Interdisciplinary research	Draws on knowledge from different disciplines and provides synthesis for one holistic goal
Multidisciplinary research	Draws on knowledge from different disciplines but each expert brings only their own perspectives/ goals
Research impact	The effect or application of research outside of academia
Transdisciplinary research	Draws on knowledge from different disciplines and different perspectives (e.g. academic, industry, government etc.) to provide synthesis for one holistic goal

Table 1
Key career challenges experienced by transdisciplinary ECRs in conservation.

	Challenge	Description
1	Limited time and support to learn a new discipline	Transdisciplinary ECRs face time and support constraints in bridging between disciplines, as there are limited training programs and scholarships available that allow a researcher to spend time upskilling in a second discipline.
2	Limited mentorship	Mentorship in transdisciplinary research often comes from ECRs rather than senior role models (if at all), leaving ECRs with fewer experienced guides to navigate the complexities of transdisciplinary work.
3	Disciplinary language barriers	Disciplinary language barriers impede effective communication and comprehension in transdisciplinary research, affecting manuscript reviews and grant applications.
4	Incompatible metrics of success across fields	Incompatible metrics of success across disciplines create challenges in evaluating career achievements for transdisciplinary researchers, and often decrease a researcher's standing in any single metric.
5	Academic structural barriers	Structural barriers in academia, such as unclear career paths and promotion evaluations based on department-specific contributions, disadvantage transdisciplinary researchers as they typically don't recognise contributions external to academia.
6	Divergent metrics of real-world impact	Translating research to impact faces challenges in defining and measuring success across fields, based on differences in collaborators and areas of influence between disciplines.
7	Lack of trust between disciplines	Differences in the agendas driving research priorities (both perceived and real) between disciplines can lead to mistrust between fields.
8	Risk and uncertainty tolerances across fields	Tolerable levels of project risk and uncertainty vary across disciplines, influencing decision-making and project success in conservation and restoration efforts.

transdisciplinary mentors may not exist, it is important that ECRs 'pave the way' for postgraduates and emerging postdoctoral research fellows by taking on mentorship roles where possible (Merga and Mason, 2021). While little can be done to bridge the transdisciplinary gap between ECRs and senior academics, positive peer relationships can foster increased research outputs and thus career success (Merga and Mason, 2021). It is also important for supervisors with more 'siloed' research skills to recognise when they cannot provide the full spectrum of skills required for transdisciplinary ECRs, and instead connect them to mentors in other disciplines

Recommendation 3: Improve research translation

There is an opportunity for transdisciplinary researchers to translate research between fields, allowing single-field experts to understand and utilise research not previously available to them. For example, Twomey et al. (2022) published a paper highlighting how seagrass interacts with waves and sediment to reduce/cause erosion. While this is obvious for coastal engineers, the authors broke down the equations and explained in detail (using figures) how these coastal dynamics evolve for a non-engineering audience, typically ecologists, environmentalists, and managers. While this can be viewed as 'reinventing the wheel', novel conclusions can still be drawn when explaining the implications of the synthesised science for a new field. We suggest that ECRs embrace a translational approach by breaking down complex field-specific knowledge so that it may be utilized by broader audiences. Journal editors could encourage and facilitate transdisciplinary contributions by inviting papers that translate key concepts for different fields. Additionally, special issues or research topics could be developed that highlight transdisciplinary research.

Recommendation 4: New metrics for transdisciplinary representation

We cannot change the entire metrics of success across fields overnight, however, the development of novel classifications for transdisciplinary research is vital to distinguish these researchers from traditional single-discipline experts. In Australia, all publicly funded science is classified into unique 'Field of Research' or FoR codes. However, the onus is often on the researcher to select the appropriate FoR codes in grant applications, despite their research being less or not-at-all specific to any pre-existing FoR codes, which are then critically evaluated by reviewers. The lack of direct alignment of transdisciplinary research to research codes can therefore be a detriment during grant selection. For example, the research of AT can be placed into with 'Ecological Applications, 'Environmental Engineering', 'Other Engineering', and 'Oceanography', yet these do not encapsulate the work of an 'Ecological Coastal Engineer'. Similarly, the terms 'Climate change science' and 'Econometrics', 'Climate change impacts and adaptation', all describe the research of MK, while any term individually does not offer a comprehensive description. To mediate this, past work has developed simple methods of identifying transdisciplinary research (see Kiatkoski Kim et al. (2022)), but such tools have yet to be widely adopted.

In addition, when finding reviewers for transdisciplinary grants it can be very difficult to find personnel with the right mix of expertise. For example, one reviewer might be able to review an 'engineering' project but not understand the 'ecology'. Whereas another reviewer could be an ecologist with no engineering knowledge. Both reviewers might fail to grasp the topic and give the grant a low score, regardless of its actual merit. Therefore, we need reviewers to understand that there are no FoR codes that encapsulate the expertise of transdisciplinary ECRs, especially when we are often required to only provide three FoR codes to describe our position.

Recommendation 5: Acknowledge and reduce structural barriers

Addressing the lack of clear career paths and senior academic positions within transdisciplinary research requires multiple changes to traditional institutional structures. Firstly, establishing departments or research centres specifically aimed at transdisciplinary research and collaboration would highlight the importance of transdisciplinary studies and foster a greater sense of collaboration and mentorship within conservation science. Creating tenure-track positions specifically aimed at transdisciplinary scholars within these structures may also help incentivize this type of research and would deliver mentoring pathways for ECRs and HDR students alike. Additionally, revising promotion and tenure criteria to value and reward collaborative, cross-disciplinary work is crucial. This could be achieved through a greater recognition of the challenges in publishing transdisciplinary research within the 'research opportunity' and 'performance evidence' sections of promotion applications. Finally, establishing funding initiatives and grants specifically for transdisciplinary research projects and collaborations would further encourage researchers to explore and be exposed to diverse fields. Grant assessments often lack transparency, and it is unfair for proposals to be rejected because assessors' area of expertise do not align with all of the disciplines in the proposal. Aligning assessors' expertise with the specific disciplines in the grant and publicly reporting their areas of expertise in the feedback could help address this issue. By removing and altering these structural barriers for transdisciplinary science, universities would be providing a more supportive ecosystem that acknowledges and values transdisciplinary contributions to conservation science. In turn, universities that provide strong research environments benefit from opening the gate to industry funding and student placement opportunities that are more common in transdisciplinary research than in single-discipline, blue-skies fields (Scholz, 2020).

Recommendation 6: Measuring real-world impact: new metrics for success

While transdisciplinary ECRs are already recognised for their valuable contributions by industry (Scholz, 2020), academic employers need to consider metrics other than traditional research outputs (citation count, h-index, prestigious grants) when assessing candidates for post-doctoral positions. Frequently, the outputs of transdisciplinary ECRs extend beyond conventional academic metrics, emphasising practical applications and real-world relevance (Belcher et al., 2016). It is also important to note research outputs from non-academic organizations or co-authors have been shown to frequently not be recognised by large scientific databases such as Web of Science (Koier and Horlings, 2015). To better appreciate the value of research, particularly in applied conservation, academic institutions may need to shift their focus from prestige-centric metrics to those reflecting the tangible and meaningful impacts achieved by transdisciplinary scholars. Future metrics that better encapsulate the quality of transdisciplinary research may be focused on relevance, credibility, legitimacy and effectiveness as has been outlined in proposed assessment frameworks (Belcher et al., 2016).

Recommendation 7: Building trust between disciplines

Addressing the lack of trust between fields in transdisciplinary research involves proactive measures to bridge communication gaps and foster mutual understanding. To overcome disciplinary language barriers, initiatives such as interdisciplinary training programs or workshops can be implemented, encouraging researchers from different fields to engage in shared learning experiences. Establishing interdisciplinary teams early in the research process, comprising experts from diverse backgrounds, can help build trust through collaborative problem-solving. Between academia and stakeholders, participatory workshops and co-participation can help nurture trust and thus produce more effective conservation solutions that bridge science and traditional ecological knowledge (Turnhout et al., 2020; De La Rosa et al., 2024). However, power asymmetries must be considered and mitigated (Kareem et al., 2022; Strumińska-Kutra and Scholl, 2022; De La Rosa et al., 2024). Finally, creating platforms for regular and open communication and collaboration, such as interdisciplinary seminars or conferences, allows researchers and stakeholders to exchange ideas and build familiarity with each other's perspectives (Kareem et al., 2022).

Recommendation 8: Project risk across fields

Transdisciplinary researchers must balance the perspectives on risk observed by the two (or more) fields and manage them effectively across fields (Section "Ecological engineering"). Here, we are referring to 'on the ground projects' such as infrastructure development or restoration projects, and 'risk' refers to the 'risk of project failure' that may be associated with environmental, societal, financial or reputational losses. Different stakeholders on a project will have different tolerable levels of risk. Improving the integration of diverse perspectives and approaches, especially when dealing with risk and uncertainty in conservation or restoration projects, requires a collaborative and inclusive framework. In coastal restoration for example, establishing transdisciplinary project teams that include social scientists, ecologists, and engineers both from academic and non-academic backgrounds can facilitate a holistic understanding of the challenges and potential solutions. Developing standardized risk assessment protocols that incorporate input from all disciplines involved can help align expectations.

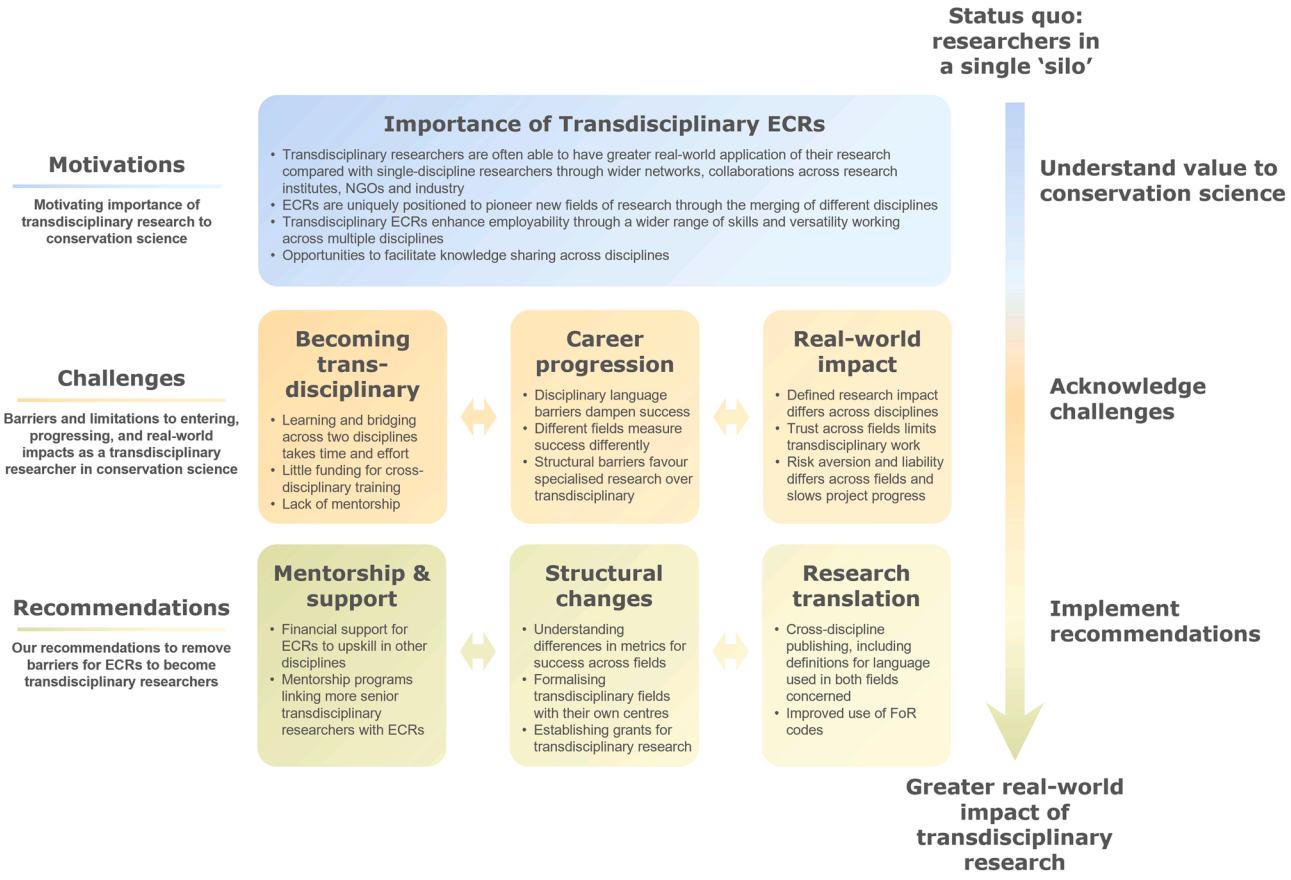


Fig. 1. Roadmap highlighting the motivations, challenges and suggested solutions to enhance career progression for transdisciplinary ECRs.

Case studies of transdisciplinary research pathways in conservation

This section presents four case studies that highlight how a transdisciplinary approach in conservation has shaped each scientist's research career and impact. Each case study reflects one author's experience, demonstrating the diverse skills and expertise (e.g. engineering, economics, management and social science) that contribute to conservation beyond traditional boundaries.

Ecological engineering

Academic engineers who have worked in consultancy typically have a solid understanding of how to 'get projects done' and can leverage this knowledge to improve the likelihood of ecological and environmental projects getting 'over the line'. For example, coastal engineering projects typically have anthropocentric goals, such as reducing flooding and erosion in coastal communities, while coastal ecology projects often aim to advance eco-centric goals such as conserving biodiversity (Mitsch, 2014). Merging coastal engineering and coastal ecology into the transdisciplinary role of an Ecological Engineer allows the ECR to progress an ecological project through the delivery of coastal engineering objectives. Ecological engineering not only bridges the engineering-science divide (Dunlop et al., 2023), but by combining industry project know-how with good ecological research often fills the gap to produce impactful research through project delivery.

Climate economics

The processes of climate change are firmly rooted within the natural sciences (Arias et al., 2021) and yet, climate change is the result of one of the largest-scale market failures (Stern, 2007) and has numerous implications across different economic sectors (Carleton and Hsiang, 2016). As such, climate change is inherently a transdisciplinary topic which is increasingly demanding transdisciplinary approaches, for example to evaluate the economic consequences of physical climate impacts and their policy implications (Burke et al., 2016). Attempts from separate disciplines to address such transdisciplinary questions often mis-apply or mis-interpret methods from across the disciplinary-divide (Auffhammer et al., 2013), but ECRs in this area can strongly benefit from both physical climate science and economics. In particular, opportunities to bridge perspectives and methods, while identifying unique research questions can bring high-impact research outcomes and assist in career progression. Moreover, demand for information on climate risks is rising within institutional bodies and the private sector, presenting unique opportunities for those able to translate the physical risks of climate change into the language of economics. For example, collaboration between climate scientists and the European Central Bank brought access to new data, methods, perspectives and unique opportunities for the dissemination of research outcomes when assessing the impact of heat extremes on food inflation (Kotz et al., 2023).

Environmental management

Environmental managers work at the intersection of complex social and ecological systems to find solutions with positive outcomes for people and nature. For instance, managing the global impacts of mining is critical to sustainable development and a clean energy future (Ali et al., 2017). However, in recent years, the mining industry has become far less attractive to young people (Abenov et al., 2023). Environmental management researchers who work with the mining industry have an opportunity to have real-world conservation impacts, considering that over half of the world's mining projects remain undocumented (Maus and Werner, 2024), new mines for clean energy threaten biodiversity (Sonter et al., 2020), and the first deep-sea mining operations could begin this decade (Hyman et al., 2022). Early career researchers, especially those with experience in both mining engineering and environmental sciences, have a unique opportunity to inform ecologically responsible measures to avoid, minimise, restore, and offset the impacts of the current and future mines (Sonter et al., 2023). Interdisciplinary research efforts could transform the future trajectory of the mining industry to re-balance the sustainable use and conservation of natural resources.

Social ecology

The core of conservation actions and interventions is almost always the environment. Focusing solely on the environment, without looking deeper into the needs of the community surrounding it, can create public backlash against conservation policies and limit their effectiveness (Turnhout et al., 2020). Following the concepts of total economic value (Plottu and Plottu, 2007) and Maslow's hierarchy of needs (McLeod, 2007), individuals are more likely to care for the environment when their core needs are fulfilled. Merging management efforts with a focus on the social aspect of conservation can greatly benefit conservation impact and provide more socially robust programmes (Turnhout et al., 2020), as the focus then becomes more about how protection of the environment can contribute (or become an incentive) to fulfilling these core needs. Only then will communities care to protect their surrounding environments. This in turn changes human-environment interactions from one of exploitation to stewardship, as it would be more beneficial to protect the environment than to exploit it. Ignoring the social aspect of conservation management, such as through blanket bans, is generally ineffective (Cooney and Jepson, 2006), and wildlife protection can cause backlash (Indraswari et al., 2020; DeMotts and Hoon, 2012), while proper implementation can create beneficial impacts. Proper management remains essential. Communities often are more willing to protect an area when there are clear benefits to wildlife protection (Tisdell and Wilson, 2002) and environmental protection (Marlina and Astina, 2020).

Conclusion

Challenges to career and research progression for ECRs are systematic, and while transdisciplinary research is beneficial to conservation science, this career path can provide additional challenges. Drawing on the authors own experiences, our case studies demonstrate the inherent complexity of modern conservation problems, and the need for modern transdisciplinary research solutions to address them. This work provides recommendations on how to improve the incentives for ECRs and the effectiveness of transdisciplinary science for real-world impacts, although systemic changes are required. By removing barriers to transdisciplinary ECR career and research success, ECRs are able to bridge knowledge silos across disciplines and work within academia, government, industry, and with end-users, to progress real-world solutions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was supported by The University of Queensland's Centre for Biodiversity and Conservation Science.

References

Abenov, T., Grabbert, T., Franklin-Hensler, M., Larrat, T., 2023. Has Mining Lost Its Luster? Why Talent Is Moving Elsewhere and How to Bring Them Back [Online].

Available: https://www.mckinsey.com/industries/metals-and-mining/our-insights/has-mining-lost-its-luster-why-talent-is-moving-elsewhere-and-how-to-bring-them-back. [Accessed 12 February 2024].
Ali, S.H., Giurco, D., Arndt, N., Nickless, E., Brown, G., Demetriades, A., Durrheim, R., Enriquez, M.A., Kinnaird, J., Littleboy, A., 2017. Mineral supply for sustainable development requires resource governance. Nature 543, 367–372.
Arias, P., Bellouin, N., Coppola, E., Jones, R., Krinner, G., Marotzke, J., Naik, V., Palmer, M., Plattner, G.-K., Rogelj, J., 2021. Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; Technical Summary.
Armitage, D., Arends, J., Barlow, N.L., Closs, A., Cloutis, G.A., Cowley, M., Davis, C., Dunlop, S.D., Ganowski, S., Hings, C., 2019. Applying a "theory of change" process to facilitate transdisciplinary sustainability education. Ecol. Soc. 24 (3), 20.
Auffhammer, M., Hsiang, S.M., Schlenker, W., Sobel, A., 2013. Using weather data and climate model output in economic analyses of climate change. Rev. Environ. Econ. Policy 7 (2).
Balmford, A., Cowling, R.M., 2006. Fusion or failure? The future of conservation biology. Conserv. Biol. 20, 692–695.
Bammer, G., O'Rourke, M., O'Connell, D., Neuhauser, L., Midgley, G., Klein, J.T., Grigg, N.J., Gadlin, H., Elsum, I.R., Bursztyn, M., 2020. Expertise in research integration and implementation for tackling complex problems: when is it needed, where can it be found and how can it be strengthened? Palgrave Commun. 6, 1–16.
Belcher, B.M., Rasmussen, K.E., Kemshaw, M.R., Zornes, D.A., 2016. Defining and assessing research quality in a transdisciplinary context. Res. Eval. 25, 1–17.
Burke, M., Craxton, M., Kolstad, C.D., Onda, C., Allcott, H., Baker, E., Barrage, L., Carson, R., Gillingham, K., Graff-Zivin, J., 2016. Opportunities for advances in climate change economics. Science 352, 292–293.
Carleton, T.A., Hsiang, S.M., 2016. Social and economic impacts of climate. Science 353, aad9837.
Cook-Patton, S.C., Leavitt, S.M., Gibbs, D., Harris, N.L., Lister, K., Anderson-Teixeira, K. J., Briggs, R.D., Chazdon, R.L., Crowther, T.W., Ellis, P.W., 2020. Mapping carbon accumulation potential from global natural forest regrowth. Nature 585, 545–550.
Cooney, R., Jepson, P., 2006. The international wild bird trade: what's wrong with blanket bans? Oryx 40, 18–23.
Dallimer, M., Strange, N., 2015. Why socio-political borders and boundaries matter in conservation. Trends Ecol. Evol. 30, 132–139.
De La Rosa, G., Milberg Muñiz, E., El-Hani, C.N., Ludwig, D., 2024. Navigating between promises and realities of transdisciplinary research for environmental conservation. Hum. Ecol. 52, 697–708.
DeMotts, R., Hoon, P., 2012. Whose elephants? Conserving, compensating, and competing in northern Botswana. Soc. Nat. Resour. 25, 837–851.
Dick, M., Rous, A.M., Nguyen, V.M., Cooke, S.J., 2016. Necessary but challenging: multiple disciplinary approaches to solving conservation problems. Facets 1, 67–82.
Dunlop, T., Glamore, W., Felder, S., 2023. Restoring estuarine ecosystems using nature-based solutions: towards an integrated eco-engineering design guideline. Sci. Total Environ. 873, 162362.
Game, E.T., Meijaard, E., Sheil, D., McDonald-Madden, E., 2014. Conservation in a wicked complex world; Challenges and solutions. Conserv. Lett. 7, 271–277.
Gardiner, M., Tiggemann, M., Kearns, H., Marshall, K., 2007. Show me the money! An empirical analysis of mentoring outcomes for women in academia. Higher Educ. Res. Dev. 26, 425–442.
Guerrero, A.M., Bennett, N.J., Wilson, K.A., Carter, N., Gill, D., Mills, M., Ives, C.D., Selinske, M.J., Larrosa, C., Bekessy, S., 2018. Achieving the promise of integration in social-ecological research. Ecol. Soc. 23 (3), 28.
Hertel, T.W., Irwin, E., Polasky, S., Ramankutty, N., 2023. Focus on global–local–global analysis of sustainability. Environ. Res. Lett. 18, 100201.
Hyman, J., Stewart, R.A., Sahin, O., Clarke, M., Clark, M.R., 2022. Visioning a framework for effective environmental management of deep-sea polymetallic nodule mining: drivers, barriers, and enablers. J. Cleaner Prod. 337, 130487.
Indraswari, K., Friedman, R.S., Noske, R., Shepherd, C.R., Biggs, D., Susilawati, C., Wilson, C., 2020. It's in the news: characterising Indonesia's wild bird trade network from media-reported seizure incidents. Biol. Conserv. 243, 108431.
Jones, B.A., Goodkind, A.L., 2019. Urban afforestation and infant health: evidence from MillionTreesNYC. J. Environ. Econ. Manag. 95, 26–44.
Kareem, B., McClure, A., Walubwa, J., Koranteng, K., Mukwaya, P.I., Taylor, A., 2022. Power dynamics in transdisciplinary research for sustainable urban transitions. Environ. Sci. Policy 131, 135–142.
Kiatkoski Kim, M., Douglas, M.M., Pannell, D., Setterfield, S.A., Hill, R., Laborde, S., Perrott, L., Álvarez-Romero, J.G., Beesley, L., Canham, C., 2022. When to use transdisciplinary approaches for environmental research. Front. Environ. Sci. 10, 840569.
Koier, E., Horlings, E., 2015. How accurately does output reflect the nature and design of transdisciplinary research programmes? Res. Eval. 24, 37–50.
Kotz, M., Kuik, F., Lis, E., Nickel, C., 2023. The Impact of Global Warming on Inflation: Averages, Seasonality and Extremes.
Lawrence, M.G., Williams, S., Nanz, P., Renn, O., 2022. Characteristics, potentials, and challenges of transdisciplinary research. One Earth 5, 44–61.
Ludwig, D., Boogaard, B.K., 2021. Making transdisciplinarity work: an epistemology of inclusive development and innovation. The Politics of Knowledge in Inclusive Development and Innovation. Routledge.
Ludwig, D., El-Hani, C.N., 2020. Philosophy of ethnobiology: understanding knowledge integration and its limitations. J. Ethnobiol. 40, 3–20.
Margules, C., Boedhihartono, A.K., Langston, J.D., Riggs, R.A., Sari, D.A., Sarkar, S., Sayer, J.A., Supriatna, J., Winarni, N.L., 2020. Transdisciplinary science for improved conservation outcomes. Environ. Conserv. 47, 224–233.
Marlina, S., Astina, I.K., 2020. Sustainable marine ecotourism management: a case of marine resource conservation based on local wisdom of bajo mola community in wakatobi national park. GeoJ. Tourism Geosites 32, 1317–1323.
Maus, V., Werner, T.T., 2024. Impacts for half of the world's mining areas are undocumented. Nature 625, 26–29.
McLeod, S., 2007. Maslow's hierarchy of needs. Simply Psychology 1, 1–18.
Merga, M.K., Mason, S., 2021. Mentor and peer support for early career researchers sharing research with academia and beyond. Heliyon 7.
Mitsch, W.J., 2014. When will ecologists learn engineering and engineers learn ecology? Ecol. Eng. 65, 9–14.
Montti, L., Gasparri, N.I., Grau, H.R., 2024. Telecoupling lens for integrating ecological and human dimensions of the biological invasion problem. Sustain. Sci. 19, 1–16.
Plottu, E., Plottu, B., 2007. The concept of total economic value of environment: a reconsideration within a hierarchical rationality. Ecol. Econ. 61, 52–61.
Ransdell, L.B., Lane, T.S., Schwartz, A.L., Wayment, H.A., Baldwin, J.A., 2021. Mentoring new and early-stage investigators and underrepresented minority faculty for research success in health-related fields: an integrative literature review (2010–2020). Int. J. Environ. Res. Public Health 18, 432.
Reyers, B., Roux, D.J., Cowling, R.M., Ginsburg, A.E., Nel, J.L., Farrell, P.O., 2010. Conservation planning as a transdisciplinary process. Conserv. Biol. 24, 957–965.
Scholz, R.W., 2020. Transdisciplinarity: science for and with society in light of the university's roles and functions. Sustain. Sci. 15, 1033–1049.
Sonter, L.J., Dade, M.C., Watson, J.E., Valenta, R.K., 2020. Renewable energy production will exacerbate mining threats to biodiversity. Nat. Commun. 11, 4174.
Sonter, L.J., Maron, M., Bull, J.W., Giljum, S., Luckeneder, S., Maus, V., McDonald-Madden, E., Northey, S.A., Sánchez, L.E., Valenta, R., 2023. How to fuel an energy transition with ecologically responsible mining. Proc. Natl. Acad. Sci. 120, e2307006120.
Stern, N.H., 2007. The Economics of Climate Change: the Stern Review. Cambridge University Press.
Strumińska-Kutra, M., Scholl, C., 2022. Taking power seriously: towards a power-sensitive approach for transdisciplinary action research. Futures 135, 102881.
Tisdell, C., Wilson, C., 2002. Ecotourism for the survival of sea turtles and other wildlife. Biodivers. Conserv. 11, 1521–1538.
Turnhout, E., Metze, T., Wyborn, C., Klenk, N., Louder, E., 2020. The politics of co-production: participation, power, and transformation. Curr. Opin. Environ. Sustain. 42, 15–21.
Twomey, A.J., Callaghan, D.P., O'Brien, K.R., Saunders, M.I., 2022. Contextualising shoreline protection by seagrass using lessons from submerged breakwaters. Estuar. Coast. Shelf Sci. 276, 108011.